Claims

1. Apparatus for analyzing a sound signal, comprising:

an ear model for deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over time is obtained; and

a pitch analyzer for analyzing the cleft contents map to obtain a pitch line over time, a pitch line indicating a pitch of the sound signal for respective time instants.

2. Apparatus in accordance with claim 1, further comprising a rhythm analyzer for analyzing estimates for selected inner hair cells, the inner hair cells being selected in accordance with the pitch line, so that segmentation instants are obtained, wherein a segmentation instant indicates an end of a preceding note or a start of a succeeding note.

3. Apparatus in accordance with claim 1, in which the ear model includes:

a mechanical ear model for modeling an auditory mechanical sound processing up to the inner ear (cochlea) to obtain estimates for representations of mechanical vibrations of the basilar membrane and lymphatic fluids; and

an inner hair cell model for transforming the estimates for representations of mechanical vibrations into the es-

timates for the transmitter concentrations at the inner hair cells.

4. Apparatus in accordance with claim 1, in which the ear model is operative to calculate a transmitter concentration for at least 100 inner hair cells,

wherein each inner hair cell is associated with a specified area of a modeled basilar membrane, and wherein each inner hair cell has associated therewith a different specified area of the modeled basilar membrane.

5. Apparatus in accordance with claim 1,

wherein the pitch analyzer further comprises a vibration period detector, the vibration period detector being operative for calculating a summary auto correlation function for each time period of a number of adjacent time periods using the estimates for the transmitter concentrations of the number of inner hair cells, and

wherein the vibration period detector is further operative, for each inner hair cell, to calculate at least one period between two adjacent maxima in one estimate, and to enter a result into a summary auto correlation function histogram.

6. Apparatus in accordance with claim 5, in which the pitch analyzer is operative to retrieve a maximum value from each histogram of the time sequence of histograms, the maximum value representing a pitch in the time period so that pitch line points are obtained.

7. Apparatus in accordance with claim 6, in which the pitch analyzer is further operative to build pitch line subtrajectories by combining pitch line points being close in time with respect to a time threshold and being close in frequency with respect to a frequency threshold.

8. Apparatus in accordance with claim 7, in which the pitch line analyzer is further operative to fuse pitch line subtrajectories with a minimum length and to discard any subtrajectories not fulfilling a criterion related to a minimum length and amplitude.

9. Apparatus in accordance with claim 2, in which the rhythm analyzer includes a searcher for searching a dominant estimate for a transmitter concentration in a specified time period and having a dominant frequency determined by the pitch line so that, for adjacent time periods, corresponding dominant estimates for different inner hair cells are obtained, wherein the searcher is operative to acknowledge a dominant estimate, when the dominant estimate is above a threshold.

10. Apparatus in accordance with claim 9, in which the threshold is an amplitude of an estimate having the second largest amplitude so that the dominant estimate has the largest amplitude in a specified time period.

11. Apparatus in accordance with claim 2, in which the rhythm analyzer is operative to build an onset map by calculating an onset value for a dominant estimate for a specified time period, the onset map including a sequence of onset values.

12. Apparatus in accordance with claim 11, in which the rhythm analyzer is operative to calculate an onset value such that an onset value is higher, when an onset has a stronger onset rise, compared to another onset having a weaker onset rise.

13. Apparatus in accordance with claim 11, in which the rhythm analyzer is operative to calculate an onset value such that the onset value is higher, when a starting level before an onset is lower compared to another onset having a higher starting level.

14. Apparatus in accordance with claim 2, in which the rhythm analyzer is operative to use an estimate for an inner hair cell representing a fundamental vibration or using an estimate for an inner hair cell representing at least one higher partial vibration.

15. Apparatus in accordance with claim 2, in which the rhythm analyzer is operative to build an onset histogram by combining onset values of estimates for an inner hair cell representing the fundamental vibration, and onset values of an estimate for an inner hair cell representing at least one higher partial vibration, which have a time distance smaller than a specified time distance threshold.

16. Apparatus in accordance with claim 11, in which the rhythm analyzer is operative to extract maxima from the onset histogram, wherein a time value associated with a maximum indicates a segmentation instant.

17. Apparatus in accordance with claim 1, further comprising a timbre recognition module, the timbre recognition module being operative for:

constructing a feature vector;

feeding the feature vector into a pattern recognition device; and

obtaining a result indicating a probability that at least a portion of the sound signal has been produced by a sound source from a number of different specified sound sources.

18. Apparatus in accordance with claim 17, in which the pattern recognition device is a neural network.

19. Apparatus in accordance with claim 17, in which the feature vector includes one or more selected members from a feature group including onset time of a fundamental vibration or a higher order partial vibration, a frequency of a fundamental vibration or a higher order partial vibration, an amplitude of a fundamental vibration or a higher order partial vibration, a number of an estimate for the transmitter concentration using the highest peak for the fundamental vibration or a higher order partial vibration, or a number of an estimate for the transmitter concentration being in resonance for a fundamental vibration or a higher order partial vibration.

20. Apparatus in accordance with claim 2, further comprising a transcription module, the transcription module being operative for using the pitch line segmented at segmenta-

tion instants to output a note description or a MIDI description.

21. Method of analyzing a sound signal, comprising the following steps:

deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over time is obtained; and

analyzing the cleft contents map to obtain a pitch line over time, a pitch line indicating a pitch of the sound signal for respective time instants.

22. Computer program having instructions being operative for performing a method of analyzing a sound signal when the program runs on a computer, the method of analyzing a sound signal comprising the following steps:

deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over time is obtained; and

analyzing the cleft contents map to obtain a pitch line over time, a pitch line indicating a pitch of the sound signal for respective time instants.